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Title: DYNAMIC OVERDRIVEN EXPERIMENTS FOR
EQUATION OF STATE

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DYNAMIC OVERDRIVEN EXPERIMENTS FOR EQUATION OF STATE

William W. Anderson and Michael J. Hopson, DX-1

Overdriven detonation experiments on explosives are an important source of data used to constrain the equations of state of the detonation products. The advantage of overdriven detonation experiments is that non-steady-state effects arising from the reaction zone behind the initial shock are minimized. Additionally, the use of impacting flyer plates with finite thickness allow a well-characterized steady state to be achieved and maintained for a period of time after passage of the shock.

The overdriven detonation experimental effort has been consolidated to a single technical area (Ancho Canyon). Several logistics issues have been addressed, most importantly, the identification of a replacement lot of PBX 9502 molding powder with properties most like the lot currently in use, which has been exhausted. Experimentation is continuing with the old lot, but new material has been pressed and new samples for future experiments will be machined from the new pressings.

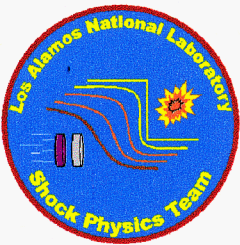
Current experimental efforts have been aimed at addressing deficiencies in the existing data set for PBX 9502 and providing a data set for other explosives that are being used to test models of chemistry effects on detonation products equations of state. Toward this end, we have completed a series of release adiabat experiments on TNT.

Recent work on PBX 9502 has focussed on the need for release adiabat data. The primary technique for obtaining data on release to pressure below 100 kbar is the plate-push technique. In the past, low-impedance plates were used to minimize the reshock in the detonation products, but the sizes of the pressure decrements in the experiments was found to be too large. New experiments have been begun with stainless steel 316 plates. This material was chosen because it has a well-constrained equation of state and it is relatively fine-grained. The primary drawback is the strength of the material, which introduces elastic waves with significant amplitudes into the experiments. We are currently performing a series of experiments to characterize the constitutive behavior of SS316. At the same time, we have begun small-scale, high-velocity plate-push experiments at the high-performance two-stage gas gun located in Ancho Canyon.

In addition to the release behavior of PBX 9502, there is a need for better characterization of the Hugoniot curve in the low-overdriven regime. We have developed a modified design for the traditional multislug Hugoniot experiment and a proof-of-concept test experiment is currently being constructed. The new experiment will allow non-standard sample dimensions to be used, which will provide a capability for thicker samples than have been used in past experiments.

New experiments are being planned to increase the data set for sound speeds at high pressure in the detonation products, as well as sound speeds in the partially released state. Plans are also under way to do experiments to study gas-cushion effects in PBX 9501 and PBX 9502 and to perform side-by-side comparisons of the old research lot and the new research lot.

DYNAMIC OVERDRIVEN EXPERIMENTS FOR EQUATION OF STATE



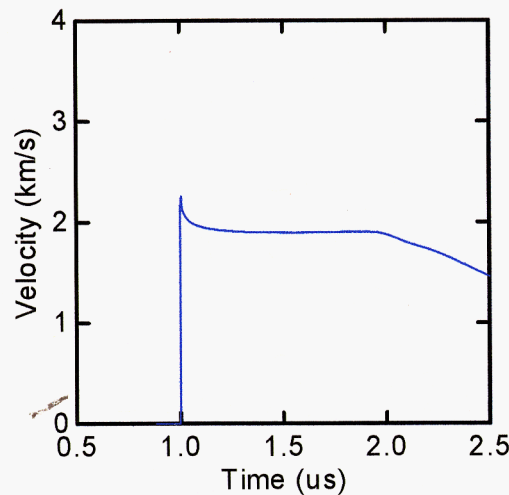
Bill Anderson and Mischa Hopson
DX-1



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Davis, Mark Byers, Frank Abeyta, Francis Sena*

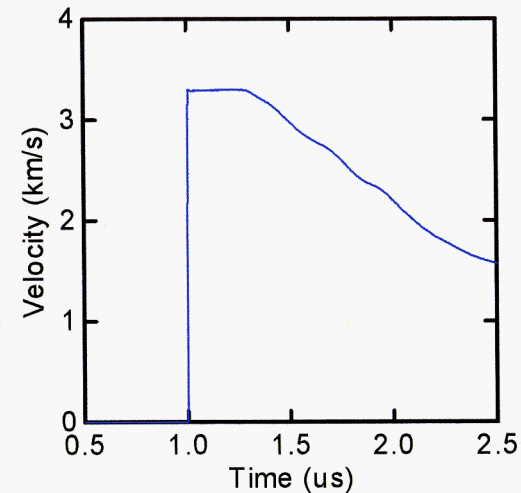
Overdriven Equation of State Experiments

- Motivation
 - Characterize performance of explosives
 - Provide data in support of EOS model development and code validation
 - Overdriven experiments used to minimize non-steady-state issues resulting from reaction zone



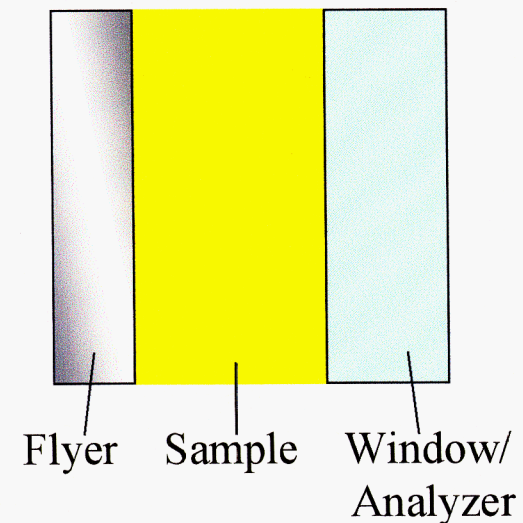
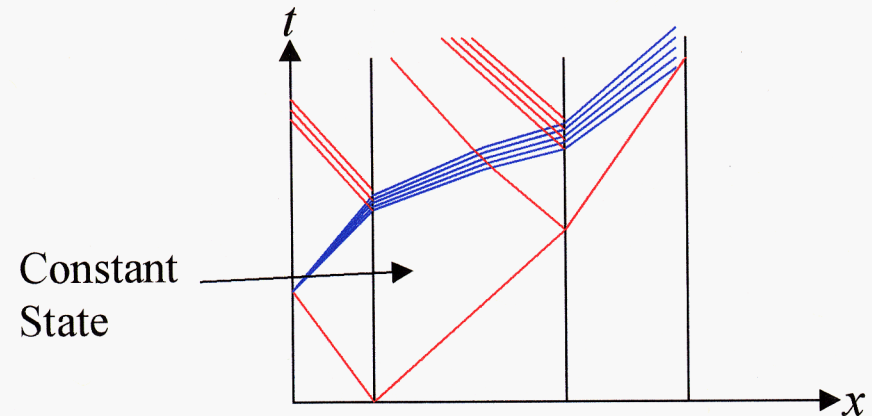
Near C-J, showing
pronounced reaction
zone

Highly-overdriven,
showing minimal
reaction zone
effects



Why Overdriven Experiments?

- Extend region of parameter space
- Supported wave produces constant state (no Taylor wave)
- Reaction zone is shortened

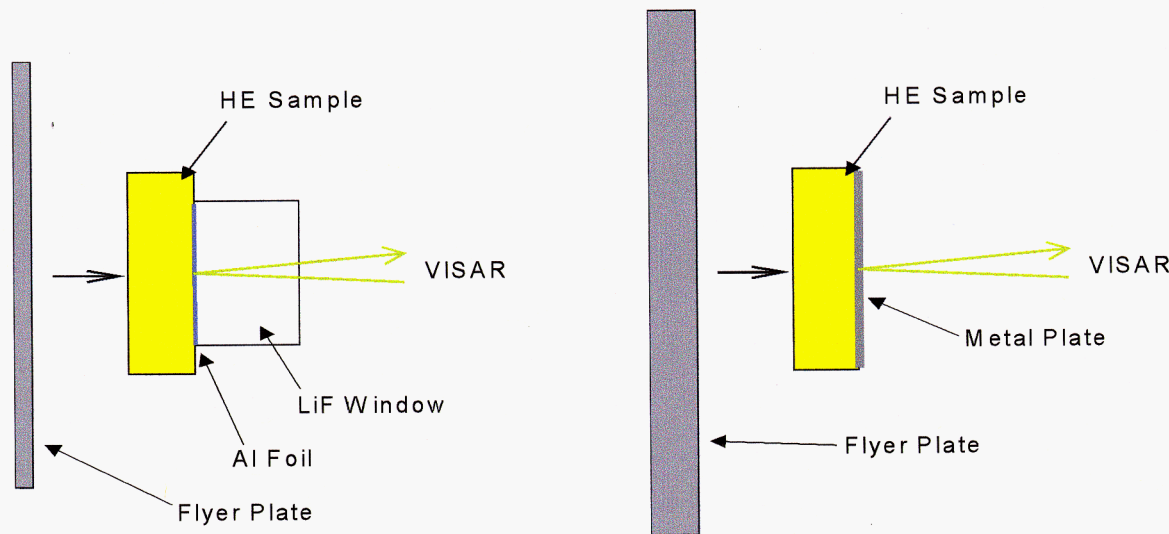


Activities and Issues

- Relocated Outdoor Explosive Firing to Ancho Canyon
 - Explosives Transport
 - Delivery of new components
- Identified New Research Lot of PBX 9502
 - Current lot almost expended
 - New lot is very similar
- Started New Plate-Push Experiments
- Completed Planned TNT Experiments
- Preparing test shot for redesigned multislug Hugoniot experiment

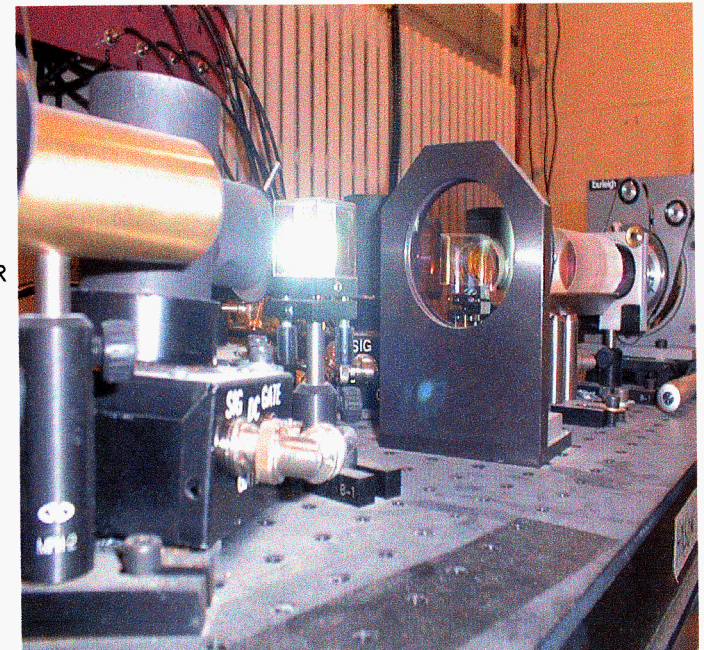
Two Types of VISAR Experiments

VISAR (Velocity Interferometer Suitable for Any Reflector) uses Doppler shift of light reflected from a surface to track velocity of the surface



Window Shock/Release

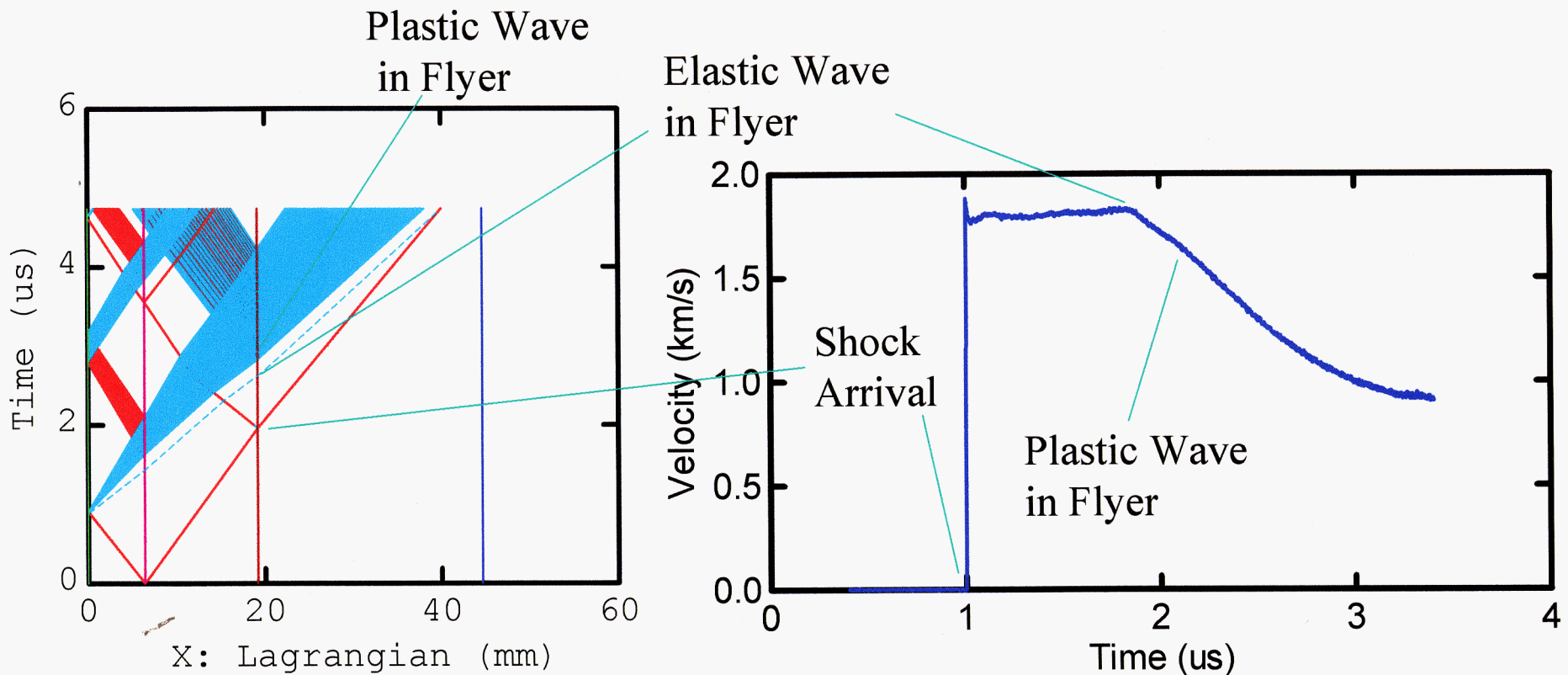
Plate-Push



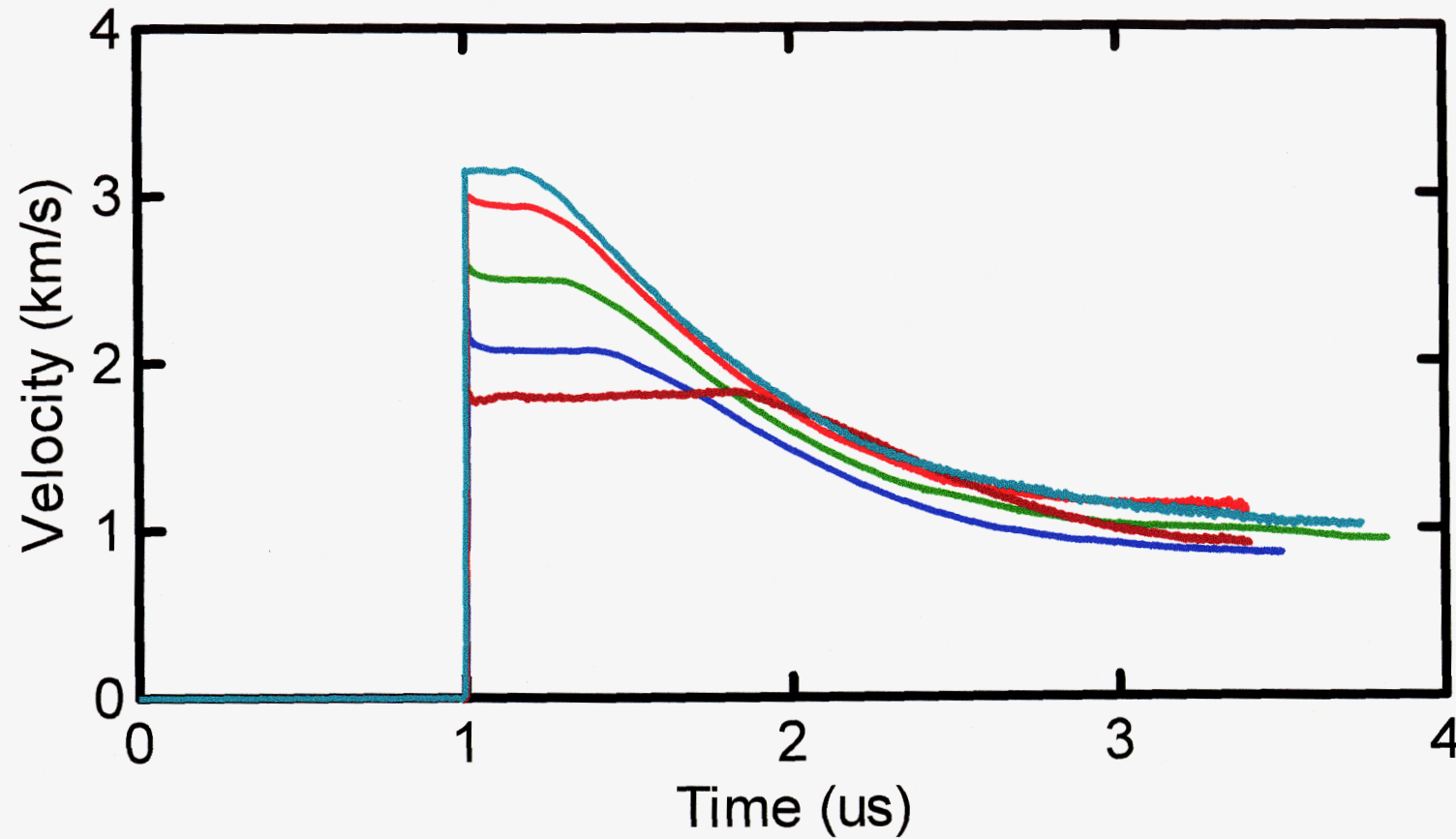
Window Release Experiments on TNT

Purpose: Characterize EOS of carbon-rich explosive

Method: Observe release behavior in order to map out continuous region of release adiabat



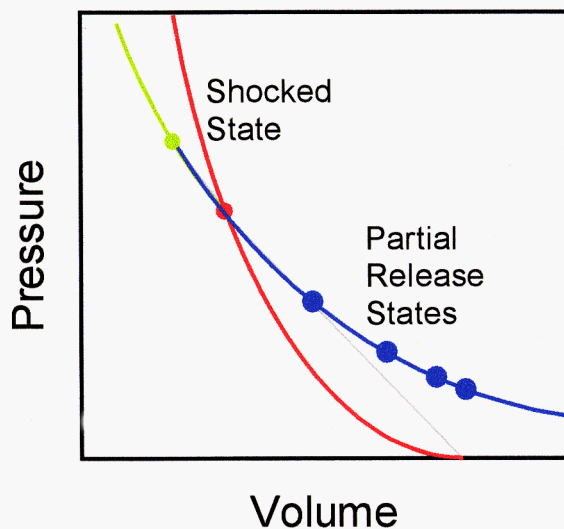
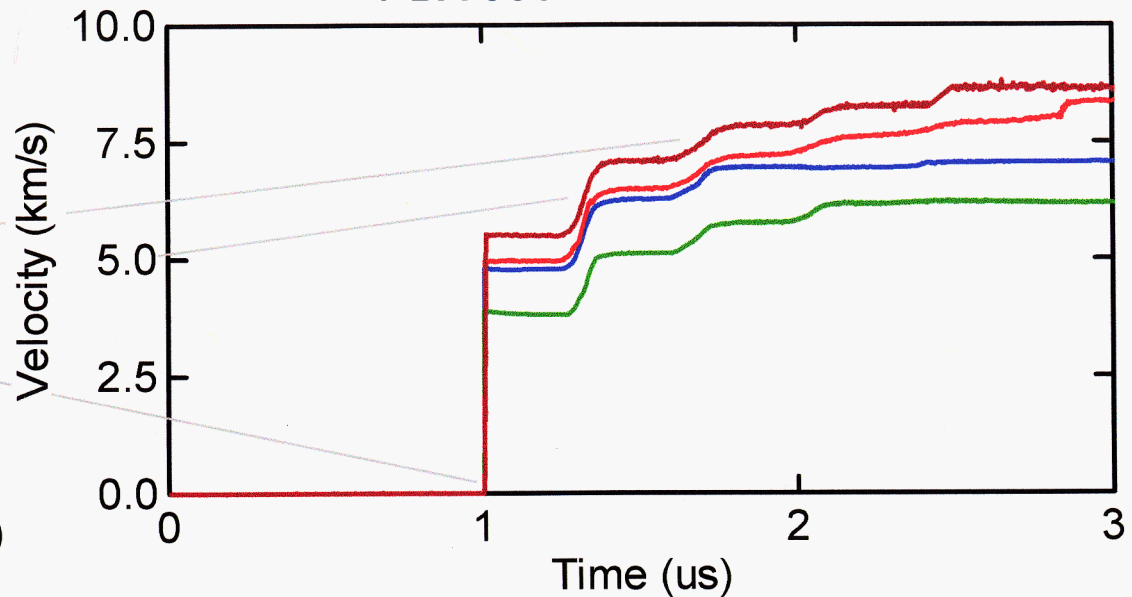
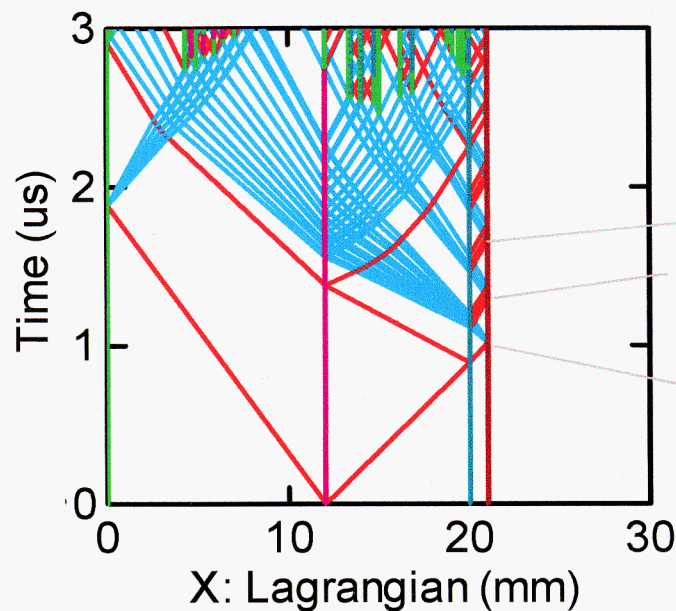
Release Experiments on TNT



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VISAR Plate-Push

PBX 9502/TiAl6V4



Reverberated release fan in plate provides stepwise measurement of states on release adiabat.

First interaction with plate is a reshock event.

Stainless Steel 316

Selected for new series of plate-push experiments

Advantages

- Higher impedance than Ti or Al produces smaller release steps
- No phase changes to complicate analysis
- Small grain size
- Well-studied

Disadvantages

- Higher impedance causes substantial reshock of detonation products
- Significant elastic strength

Equation of State and Constitutive Properties of SS316

Existing EOS data include Hugoniot and sound speeds in shock-compressed state. Experiments under way at Ancho Canyon two-stage gun to characterize constitutive behavior at high pressures.

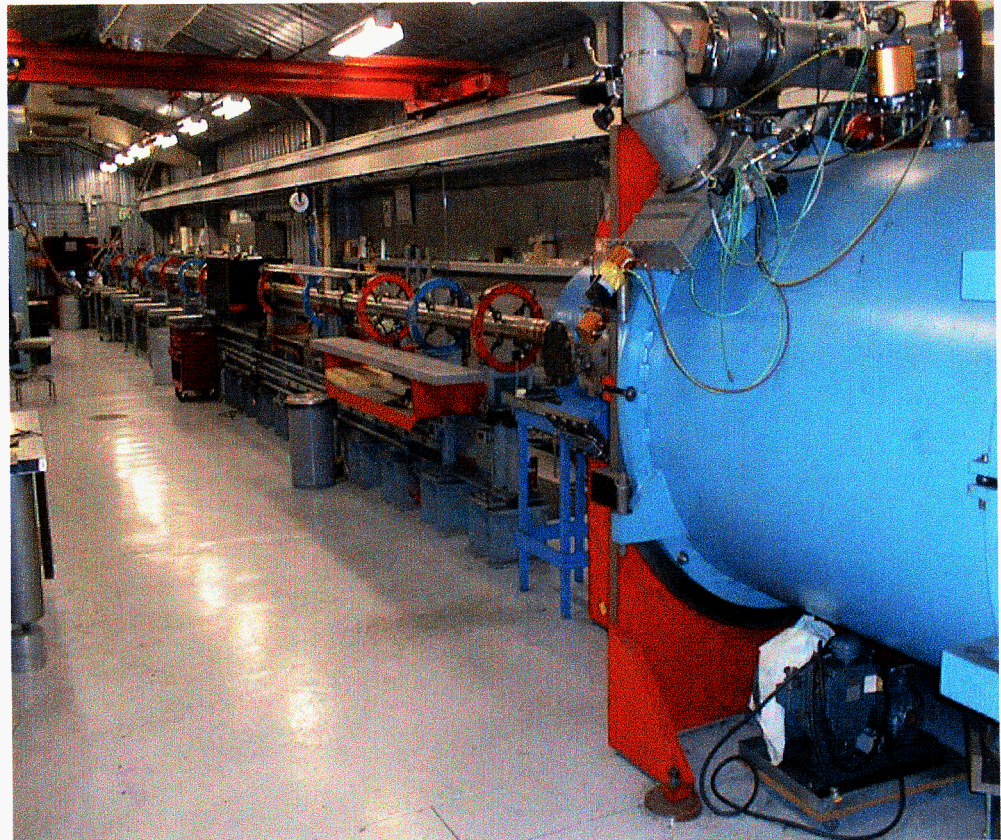
$$\rho_0 = 7.960 \text{ g/cm}^3$$

$$C_0 = 4.464 \text{ km/s}$$

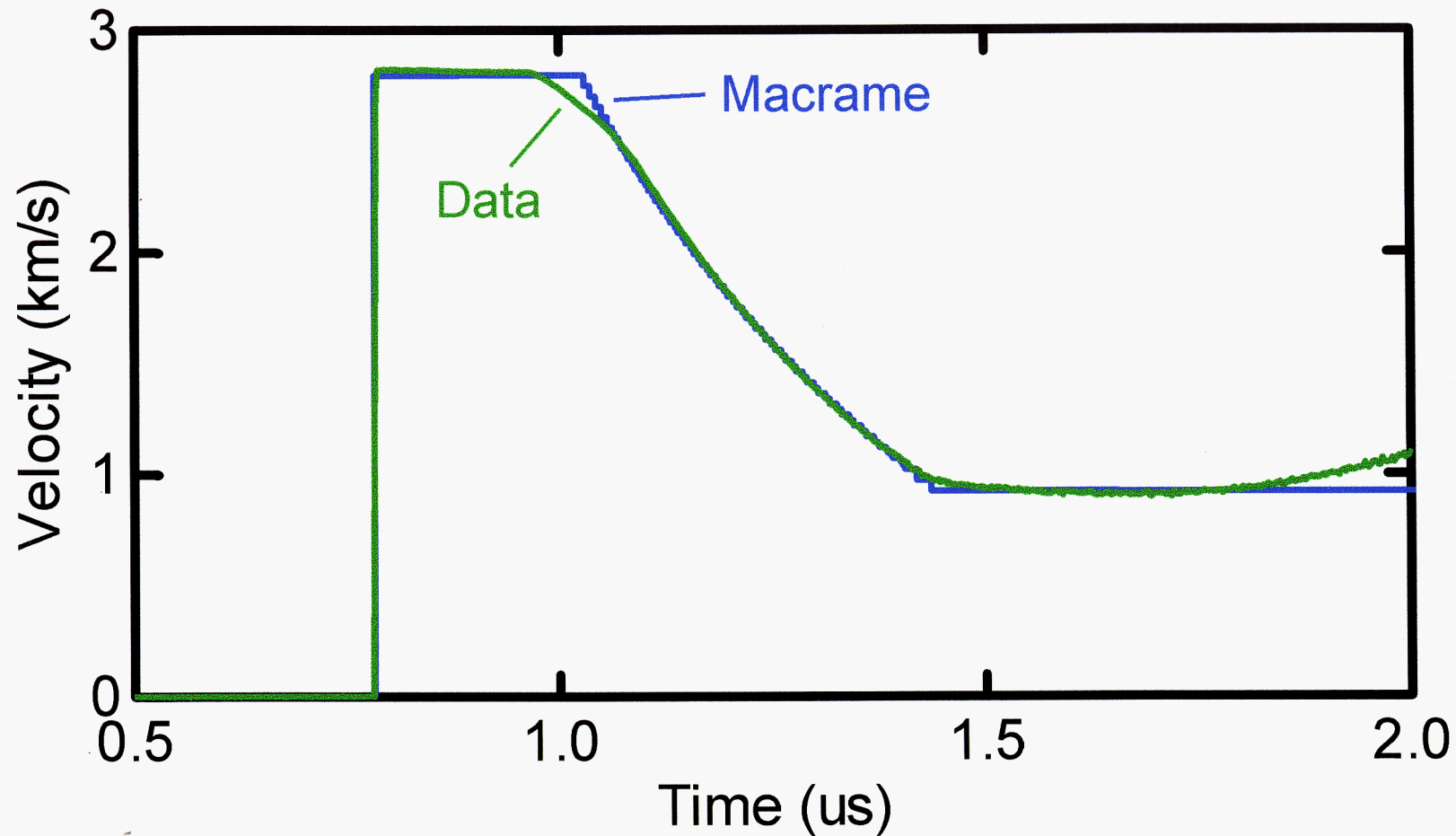
$$s = 1.544$$

$$\gamma_0 = 2.17$$

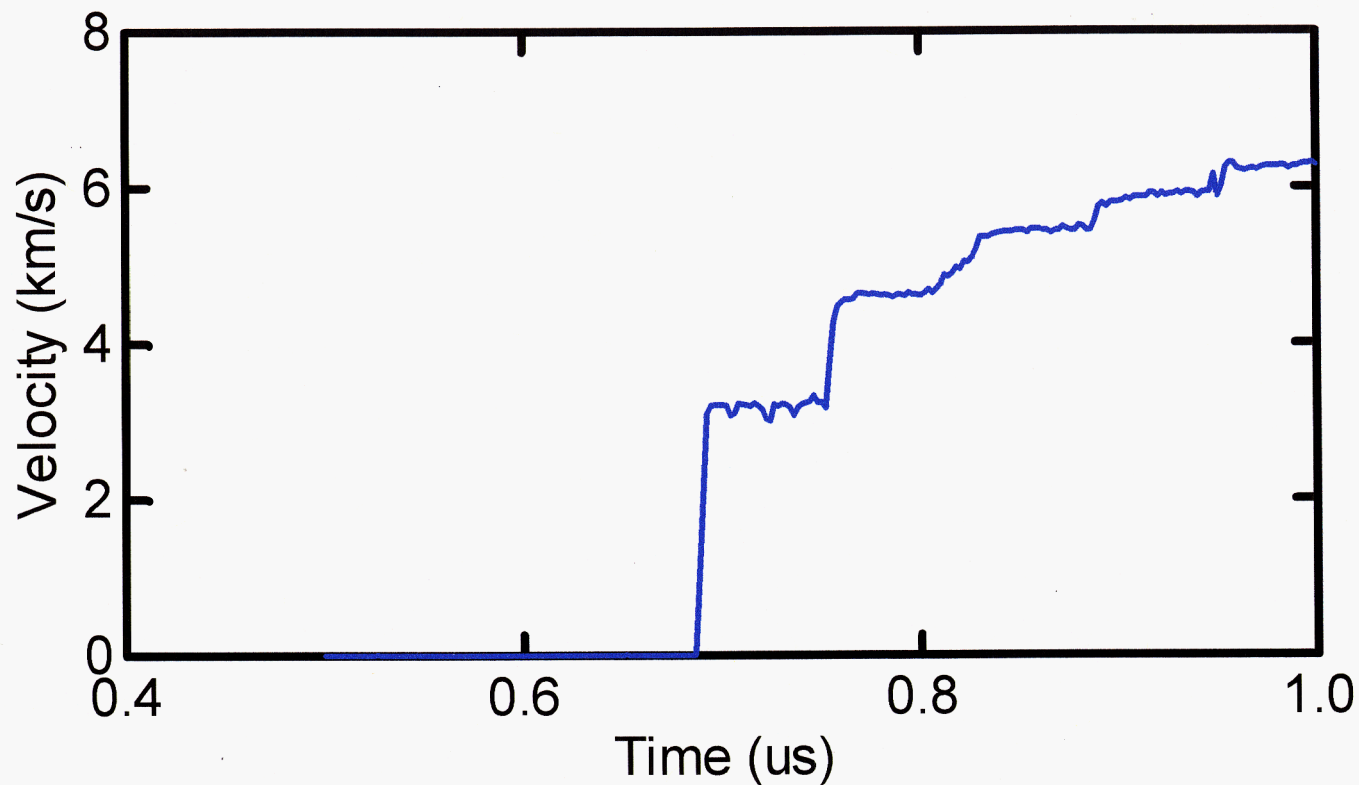
$$\rho\gamma \text{ constant}$$



Equation of State is Correct



PBX 9502/SS 316 Plate Push



Hugoniot Curve

- Locus of end states of shock compression process
- Hugoniot curve is *not* a thermodynamic path
- Curve is constrained by Rankine-Hugoniot jump conditions and EOS of material:

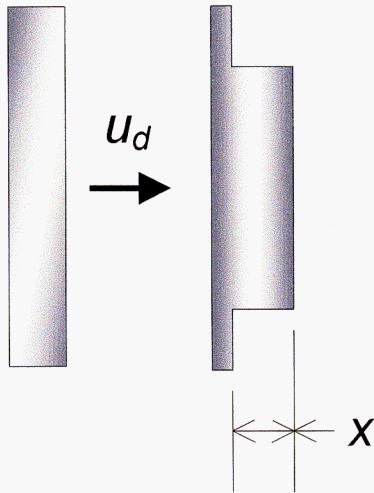
Conservation of Mass $\frac{\rho_0}{\rho} = 1 - \frac{u_p}{U_s}$

Conservation of Momentum $P - P_0 = \rho_0 U_s u_p$

Conservation of Energy $E - E_0 = \frac{1}{2} u_p^2 = \frac{1}{2} (P - P_0)(V_0 - V)$

Measurement of Hugoniot (Traditional Shock Wave Experiment)

Flyer Plate Target

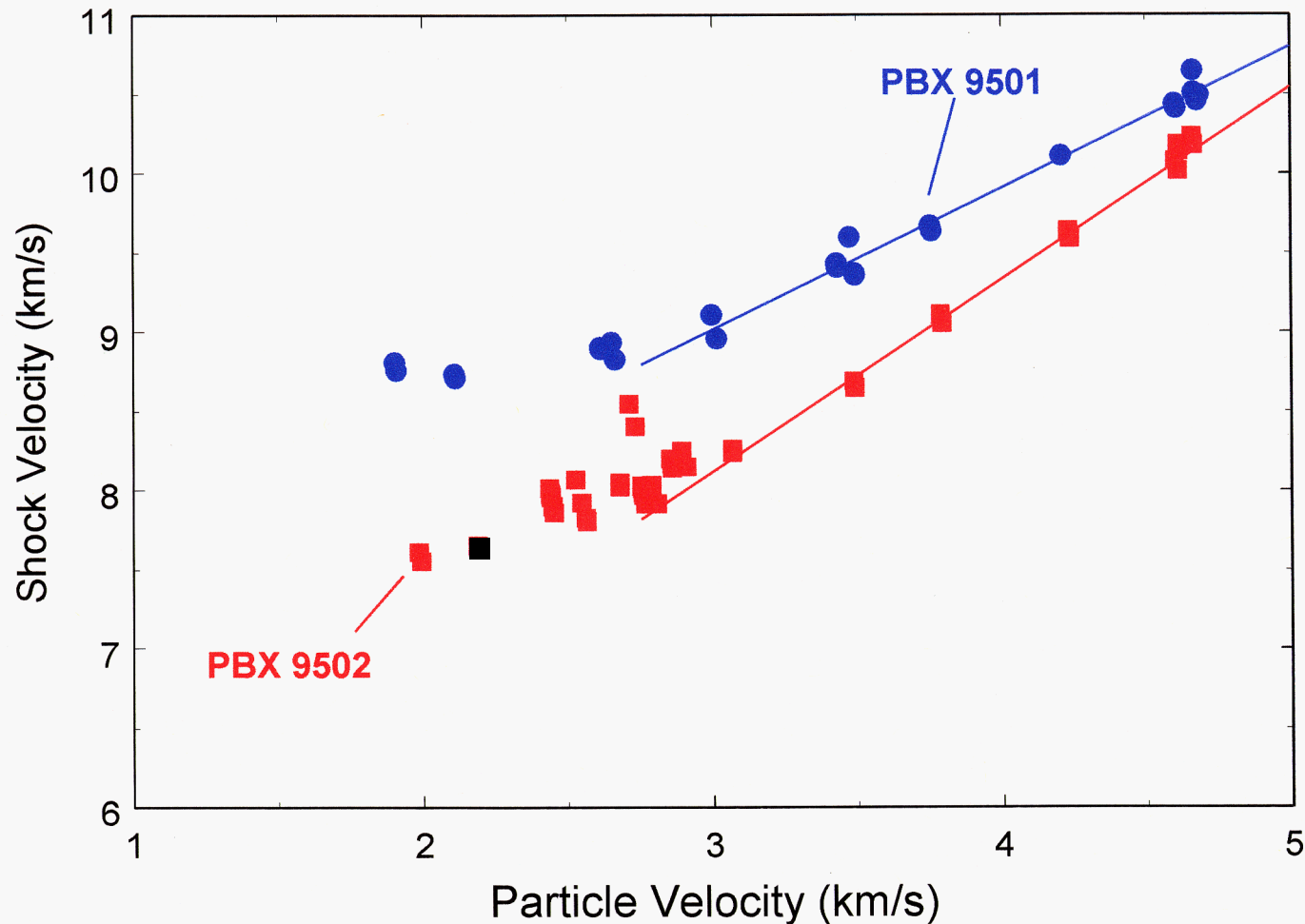


Measurement of shock transit time give U_s from x/t .

Requirement for P and u_p to be continuous, known u_d and flyer properties allows u_p , P , V , and E to be obtained.

Low-Pressure Overdriven Hugoniot for PBX 9502 is Not Well-Constrained

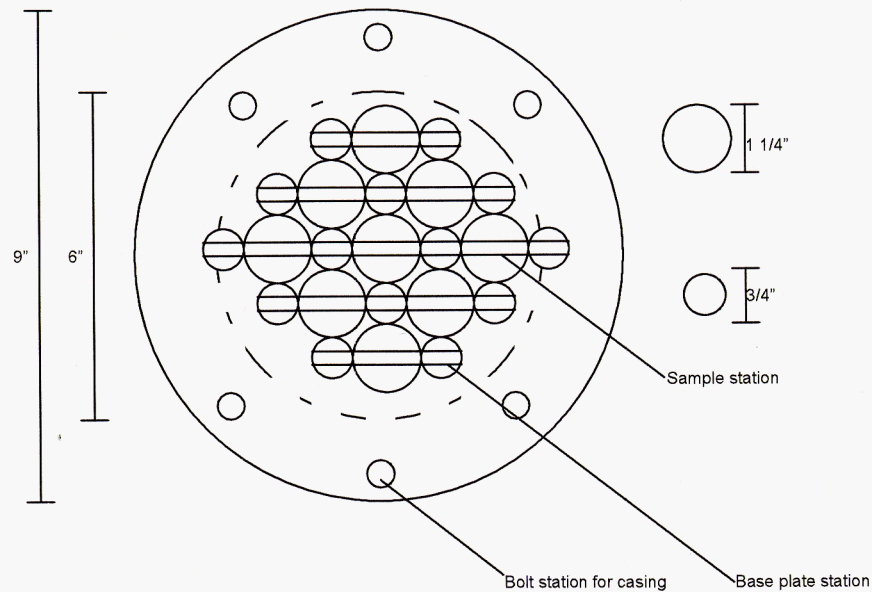
High Explosive Hugoniot Data



Modification of Multislug Hugoniot Experimental Technique

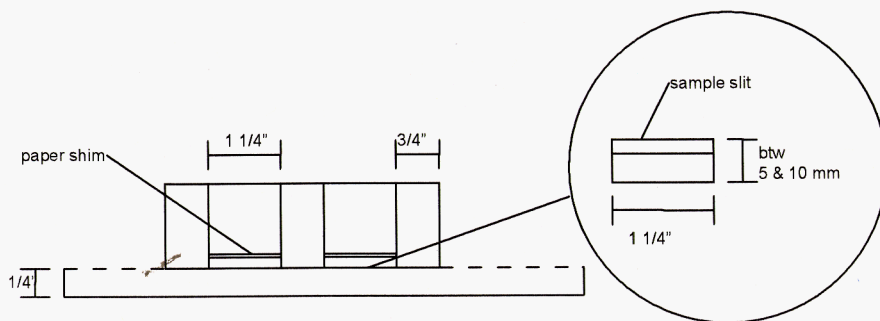
- Thick reaction zone in PBX 9502 causes problems with Hugoniot measurements in low-overdriven regime
- Multislug experiment pioneered in GMX-6 being modified to allow longer run distances in samples

New Design of Multislug Experiment



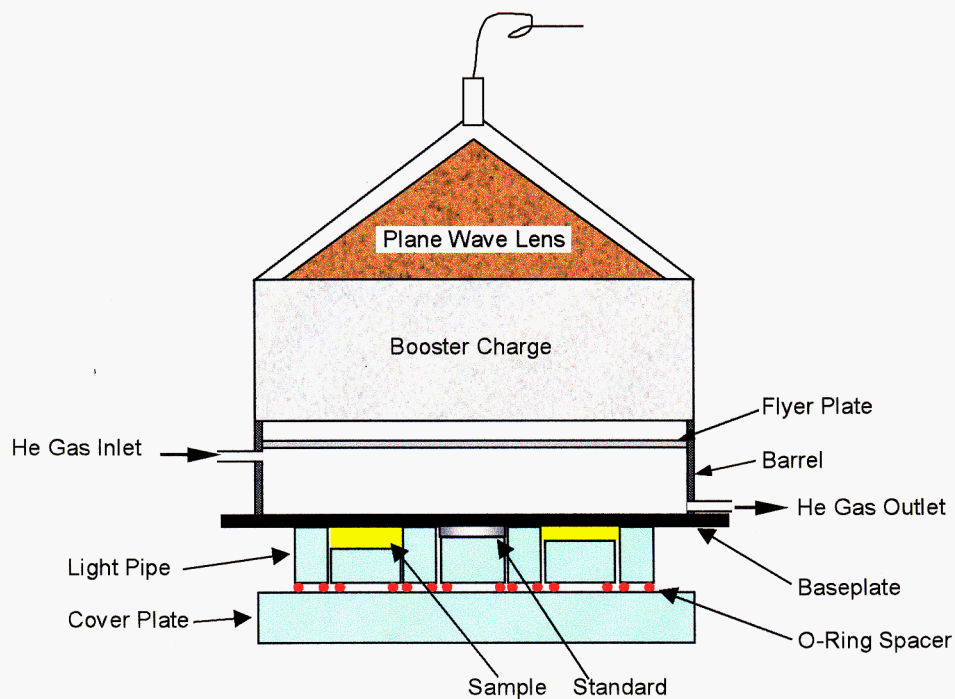
Baseplate Layout

New design allows for different size stations for samples or standards and baseplate. Larger sample diameters allow thicker samples to be used.



Detail of Flash Gap

Multislug Experiment



Future Plans

- Experiments to characterize sound speeds
- Comparison experiments between old and new lots of PBX 9502 molding powder
- Gas cushion effects in PBX 9501 and PBX 9502

Summary

- Relocated Explosive Firing Activities
- Completed TNT Release Experiments
- New Plate-Push Experiments on PBX 9502
- Characterization of SS316 as Plate Material
- Redesign of Multislug Hugoniot Experiment
- Plans for Characterization of Sound Speeds
- Plans for Gas Cushion Experiments